

Utilisation of Smart Devices in the Construction Industry: An Empirical Study in the Dominican Republic

Manuel Silverio-Fernandez, University of Wolverhampton, Wolverhampton, UK

Suresh Renukappa, University of Wolverhampton, Wolverhampton, UK

Subashini Suresh, University of Wolverhampton, Wolverhampton, UK

ABSTRACT

On a global scale, the construction sector is considered to have a high degree of decentralised information. In the Dominican Republic, the construction industry represents the most significant economic activity in the country. Smart devices and the Internet of Things create an opportunity to enhance the exchange of information in the construction sector. This article reports on the empirical findings of an investigation focused on the implementation of smart devices in the AEC sector. Findings address the status of digitalisation in the construction sector of the construction industry as well as main utilisations of smart devices. The findings are based on semi-structured interviews with fifteen professionals from nine construction organisations. The article concludes that smart devices increase efficiency in the construction industry of Dominican Republic by adding mobility, ubiquitous data access, and digitalisation of paperwork.

KEYWORDS

AEC Sector, Construction Industry, Digitalisation, Internet of Things, Smart Devices

1. INTRODUCTION

The Internet of Things (IoT) is a relatively recent paradigm that is rapidly gaining grounds and acceptance in the scenario of wireless telecommunications. This concept is based on a continuous presence of diverse objects connected to a network or other devices that can interact with each other to reach common business goals (Giusto et al., 2010).

Traditional internet consists of a global network that enables communications between computers. When connecting those computers, the main purpose of the internet is connecting the users of those computers. The traditional internet is user-centric however Internet of Things (IoT), is a network that connects things; anything can be connected to this network (Miller, 2015). The IoT interconnects uniquely identifiable embedded computing devices.

The main strength of the IoT is the high impact it will have on several aspects of everyday life and behaviour of potential users in both working and domestic fields. If effectively implemented in

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the field of Architecture, Engineering and Construction (AEC) it represents a major step towards the integration of stakeholders via autonomous information exchange.

According to Atzori et al. (2010), the IoT has an enormous potential for developing many applications in our society. By implementing this paradigm in the construction industry, regular objects would record data which can be used to build relevant metrics to users. The data obtained from the integration of the IoT with traditional construction processes can be used to enhance construction projects efficiency, and subsequently, make the industry more sustainable, by enabling regular objects to communicate with each other and collect information from the surroundings where a wide range of autonomous applications could be deployed.

Smart devices are objects capable of communication and computation which range from simple sensor nodes to home appliances and smartphones. This paper considers smart devices as the objects present in a pervasive network of the IoT (Stojkoska & Trivodaliev, 2017)). Some authors also use other terms when referring to smart devices, Azhar et al. (2015) use the terms “mobile tools”, “mobile technologies” and “mobile devices” for devices that allow professionals to get instant access to project documents, plans and specifications.

Some of the main technologies associated with smart devices in the construction industry are Cloud Computing (CC), Augmented Reality (AR), Building Information Modelling (BIM), and Geographical Information System (GIS). The main idea behind each one of these technologies are discussed below:

- CC makes applications and data available remotely, providing ubiquitous data access to its users. In the construction industry, it shows benefits such as cost reduction, mobility, flexibility and ease of maintenance (Silverio et al., 2017). Based on the nature of the construction industry and the cloud computing model, Cheng and Kumar (2012) suggest four main benefits of CC for construction collaboration and management, namely, cost, mobility, flexibility, and maintenance and updating. Whereas Brender & Markov (2013) establish the main topics of concern regarding the adoption of CC from a management point of view as: information security; privileged user access; regulatory compliance and data location; investigative support; availability and disaster recovery; and provider lock-in and long-term viability;
- AR represents a viable and efficient approach for combining virtual reality with the real world (Kamat et al., 2010). AR augments user's perception of a real-world entity by inserting relevant digital information into the real environment. Similarly, Chi et al., (2013) explain AR creates an environment where computer-generated information is superimposed onto the user's view of a real-world scene. Recent investigations suggest that the implementation of AR applications in the AEC require the development of pervasive AR solutions (Grubert et al., 2017). Pervasive AR is a continuous and pervasive user interface that augments the physical world with digital information registered in three-dimensional (3D), while being aware of and responsive to the users' context (Grubert et al., 2017). Moreover, pervasive AR is the integration of context-awareness, responsiveness and continuity into traditional AR;
- BIM integrates a 3D model for display and a data set of properties to maintain. The implementation of BIM in construction projects can increase collaboration within project teams, improve profitability, reduce costs, better time management and provides improved customer/client relationships (Chong et al., 2014);
- GIS is a system to capture, store, manipulate, analyse, manage and present all types of geographical data (Sweeney, 1999). A comprehensive review of the application of GIS in construction activities was performed by Bansal (2007), presenting solutions like subsurface profiling, construction cost estimation and quantity take-offs, materials layout at construction site, construction site layout, real-time schedule monitoring systems, route planning and topography visualisation. When GIS layout data is linked with three-dimensional (3D) site models, the whole material circulation path in the site can vividly simulated and two-dimensional GIS becomes three-

dimensional (Irizarry et al., 2013). The 3D GIS can use 3D database in distinct forms such as: imagery, digital elevation model for surface elevations, 3D model representing interior design of a building (Bansal & Pal, 2009).

The integration of BIM and GIS plays a key role in a smart construction industry, they are fundamental for the development of smart cities and they are also used together in the construction of new buildings and retrofit of old stock. For new construction projects, the integration of BIM and GIS supports applications such as supply chain management and schedule management provides efficiency (Irizarry et al., 2013; Ma & Ren, 2017).

Smart city is a municipality that uses information and communication technologies to increase operational efficiency, share information with the public and improve both quality of government services and citizen welfare. It relies on automation, machine learning and the Internet of Things. In order to work properly, smart cities applications need to manage mass data. According to Ma & Ren (2017) BIM and GIS are some of the main technologies for managing such data. BIM can create, manage and share the lifecycle data of buildings while GIS can store, manage and analyse data describing the urban environment.

This paper aims to explore the utilisation of smart devices in the construction industry. An overall explanation of the research problem is discussed in Section 2 of this paper, research methodology adopted is described in Section 3, findings are explained in Section 4, and finally, conclusions are discussed in Section 5.

2. RESEARCH PROBLEM

On a global scale, the construction sector is a fragmented sector where many stakeholders work together to successfully deliver a project. Box (2014) states that this sector has the highest degree of decentralisation of information, highest mobility and highest external collaboration when compared with other four industries, namely: software; manufacturing, finance; and media and entertainment. Also, the construction industry has the highest rate of mobile content access, this resulting in stakeholders interacting and accessing content via mobile devices more than any other sector.

Nowadays the paradigm of Industry 4.0 aims at introducing a new level of organisation and control within the current industry, thus taking the last industrial revolution to a new level of efficiency. The term Industry 4.0 is regarded as a fourth industrial revolution which defines a new level of organisation and control over the entire value chain of the life cycle of products (Rüßmann et al., 2015). One of the key players in this revolution is the IoT, which attempts to collect and analyse data and be part of the core process of all industries. According to Lee et al., (2014) the industry 4.0 relies on the IoT for converting regular machines to self-aware and self-learning machines, hence improving their overall performance and maintenance management with the surrounding interaction.

Stojkoska & Trivodaliev (2017) highlights smart devices as the core devices present in the IoT. Hence the importance in understanding the implementation of smart devices in the construction industry. Currently, there is a lack of information regarding the main utilisations given to smart devices in the AEC sector. This study focuses on exploring the main utilisation of smart devices in the construction industry.

This investigation uses the Dominican Republic construction industry as the scenario. According to the report on the Economy of the Dominican Republic (Central Bank of the Dominican Republic, 2016) on a national scale, the construction industry contributes to approximately 17.7% of the GDP and has had one of the highest economic relevance for twelve trimesters. This economic behaviour is due to the necessity of dwellings of low cost and execution of public and private projects focused on tourism, commerce and road work. Consequently, this industry has been the most significant economic activity in the country, providing employment and economic growth.

3. RESEARCH METHODOLOGY

An empirical study was made in the Dominican Republic construction industry, which has no background research on this field, yet represents one of the most important economic activities of the country. This article addresses the status of digitalisation in the construction sector of the Dominican Republic; organisational structure of construction companies in the Dominican Republic; and the utilisation of smart devices and related technologies in the industry.

As an initial step, this study followed a systematic approach for reviewing compendium of literature to examine the background of this research and define the interview questions. The search for peer-reviewed journal articles has been done via databases, initially in chronological order. Subsequently, this allowed performing a literature review. A literature review is a systematic and reproducible approach for synthesising the existing body of published work generated by researchers or scholars (Fink, 1998). Due to the ever-increasing number of academic papers (Conferences, journals and books), literature reviews have become a usual and indispensable method for synthesising a specific research field (Teuteberg & Wittstruck, 2010).

As a pilot study, a set of 15 semi-structured interviews were performed in the Dominican Republic, enquiring about: digitalisation of construction, utilisation of smart devices in construction projects, drivers, barriers and critical factors for a successful implementation of smart devices. This paper reports on the status of digitalisation in construction projects and the utilisation given to smart devices in the construction industry. The sampling technique was critical case sampling; this is a type of purposive sampling technique that is particularly useful in exploratory research which allows establishing logical generalisations. Due to the qualitative nature of this research, it was necessary to select critical companies that represent a variety of scenarios of the construction industry in the Dominican Republic.

The organisations were classified following the official company classification established in the Dominican Republic by the law 488-08 (*Law No. 488-08*, 2008) from the same country, which divides companies into micro, small, medium and large depending on their number of employees and revenue, this classification is explained in Table 1. A total of ten organisations participated in the interviews; Table 2 shows their size, nature and scope of operation, and the designation of the interviewees in each organisation.

The interviews were performed from December 2016 to January 2017; the duration was fifteen to thirty minutes. The interviews were held in the city of Santo Domingo in the Dominican Republic. The interviewees were civil engineers and architects with positions that range from resident engineers to directors of the company. The years of experience of the interviewees range from more than 2 to more than 30. Table 3 presents the background of the professionals from the construction industry of the Dominican Republic who participated in the interviews.

Table 1. Classification of companies in the Dominican Republic based on number of employees, capital and revenue

Company Type	Company Size (No. of Employees)	Active Capital (In DOP – RD\$)	Annual Revenue (In DOP – RD\$)
Micro	1 – 15	< 3,000,000.00	<6,000,000.00
Small	16 – 60	3,000,000.01 – 12,000,000.00	6,000,000.01 – 40,000,000.00
Medium	61 - 200	12,000,000.01 – 40,000,000.00	40,000,000.01 – 150,000,000.00
Large	>200	> 40,000,000.00	> 150,000,000.00

Table 2. Profile of construction organisations operating in the field of Building and Civil engineering

Contractor	Company Size	Sector	Scope of Operation	Number of Interviewees	Designation of Interviewees
DR-01	Small	Private	National	1	Resident Engineer
DR-02	Large	Public	National	1	Resident Engineer
DR-03	Micro	Private	National	1	Director
DR-04	Micro	Private	National	1	Director
DR-05	Small	Private	National	3	Resident Engineer (2) & BIM manager (1)
DR-06	Medium	Private	International	1	Project manager
DR-07	Large	Public	National	1	Project designer
DR-08	Micro	Private	National	1	Project manager
DR-09	Large	Public	National	1	Drawings coordinator
DR-10	Medium	Private	International	4	Project manager (3) & Project designer (1)

Table 3. Interviewees demographic information

No.	Profession	Position	Company Size	Sector	Experience in Construction (Years)
1	Civil engineer	Resident engineer	Small	Private	> 3
2	Civil engineer	Resident engineer	Large	Public	> 30
3	Civil engineer	Director	Micro	Private	> 2
4	Civil engineer	Director	Micro	Private	> 12
5	Architect	BIM manager	Small	Private	> 4
6	Civil engineer	Project manager	Medium	Private	> 5
7	Civil engineer	Project manager	Large	Public	> 6
8	Civil engineer	Project manager	Micro	Private	> 4
9	Civil engineer	Resident engineer	Small	Private	> 9
10	Civil engineer	Resident engineer	Small	Private	> 6
11	Architect	Drawings coordinator	Large	Public	> 4
12	Architect	Project designer	Medium	Private	> 4
13	Civil engineer	Project manager	Medium	Private	> 5
14	Architect	Project manager	Medium	Private	> 5
15	Architect	Project manager	Medium	Private	> 10

The collected data were analysed using qualitative content analysis following the guidelines of White & Marsh (2006). The coding scheme was inductive and followed the initial questions of the study as a guide for the creation of themes. After grouping the data in themes, sub-themes were created inductively. This process was used to create a “big picture” of about the status of smart devices and digitalisation in the Dominican Republic. Hence, the findings are shown as a narrative which describes the perception of the interviewed construction companies.

To assist with the data analysis, a 5-step process based on Creswell’s (2013) guide for qualitative data analysis was utilised. These steps are transcription of audio interviews; preparation of transcripts; iterative review of transcripts; coding of transcripts; generations of themes. White and March’s (2006) approach was also a useful source of guidelines for performing qualitative content analysis and developing an inductive coding scheme. The iterative review and coding of the transcripts yielded a deep understanding of the points made by the interviewees and resulted in the extracting of issues and generation of themes relating to the critical factors for a successful implementation of smart devices in the same sector.

The sample size of this study is justified on the basis of interviewing study participants until data saturation was obtained. Following the methodology established by Francis (2010), firstly, we specified a minimum sample size for initial analysis. Secondly, we specified how many more interviews will be conducted without new ideas emerging (stopping criterion). The stopping criterion used in Francis (2010) is three interviews after the data saturation is reached. The number of initial sample size is fifteen. Section 4.3 discusses the results and the achievement of data saturation.

The findings are in Section 4 as follows: Section 4.1 discussed the organisational structure and creation of innovation in the construction industry of the Dominican Republic. Section 4.2 presents the status of digitalisation in the construction sector, whereas section 4.3 addresses the utilisation of smart devices in the Dominican Republic construction industry. Section 5 discusses the conclusions of this paper and future work of this investigation.

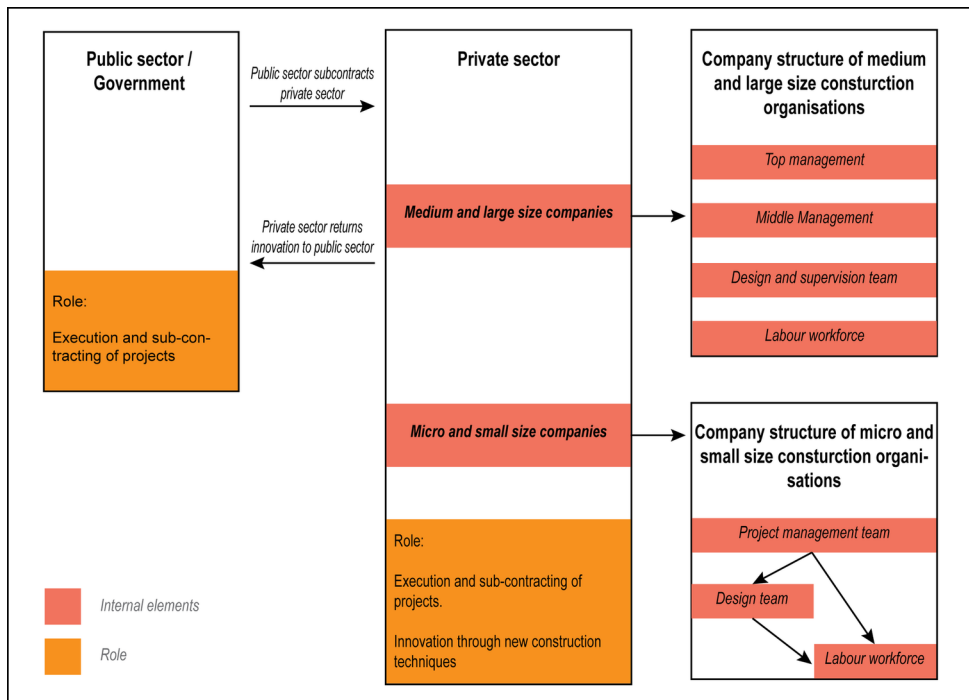
4. FINDINGS

The results from the data analysis consist of: (1) an empirical organisational structure of the construction industry in the Dominican Republic, (2) the status of digitalisation in the industry and (3) the main utilisation of smart devices in construction projects. The organisational structure of the construction sector shows the innovation cycle between the public and private sector as well as the structure within small, medium and large companies. The status of digitalisation in construction narrates the strategy and barriers of these companies to embed technology for becoming more digital based. Finally, the utilisation of smart devices is grouped into six categories which explain how professionals of the industry are using devices like tablets, smartphones and smart boards to enhance the processes of the industry.

- Organisational structure of the Dominican Republic construction industry.

Figure 1 shows the interaction between private and public sector in the construction industry of the Dominican Republic as well as the organisational structure of small, medium and large firms. The public sector has the largest economic resources. Consequently, it subcontracts to the private sector for the partial or full development of projects. Of the Dominican Republic construction industry, the public sector is known by not being innovative in comparison to the private sector. On the other hand, the large size companies in the private sector take more risks embedding new technologies into their project, if those technologies prove themselves to be cost and time-saving. Once the private sector has demonstrated a technology works in the industry, the public sector, driven by cost savings, embeds that technology into their ecosystem.

Figure 1. Organisational structure and innovation exchange in the Dominican Republic construction industry



The organisational structure of medium and large size companies has a top management level which is formed by the decision makers (see Figure 1). This group consists of one or more individuals who oversee the company trajectory and the approval of new technologic initiatives, on a lower level, there is a middle management layer which is composed of project managers of the company. These managers can implement low budget initiatives to create a case study that influences the decision makers to adopt certain technology. The design and supervision team is composed of all the professionals in all the departments of the company (architecture, engineering, finance, etc.) that design, administrate or supervise the project. This layer can try to innovate, but any innovation would be isolated unless the middle management team accepts it. The last layer is the execution workforce, which is composed of all the workers on the job site. The innovation on this layer is localised, and because of the social situation of the Dominican Republic, this layer is usually the one with less technological capability.

For small companies, the structure rotates around a project management team which is usually one person or an association of two or three professionals of the industry. This group subcontracts most of the services and depending on the company size and field of work they have a small design team.

- Digitalisation of construction

The digitalisation of processes in construction companies in the Dominican Republic varies depending on the company size, project size and leadership in the business. Larger companies are more likely to implement software systems for digitalising Request for Information (RFI), whereas the decisive factor is the leadership shown by the decision makers.

In large companies, the organisational structure represents a significant role for the introduction of new technologies. Companies with a middle management line as in Figure 1 can introduce initiatives for the implementation of new technologies.

In the current study, interviewees have shown both positive and negative perspective towards digitalisation in the construction industry.

- Positive perspective towards digitalisation

Some of the responses obtained from the interviewees regarding the status of the digitalisation of construction, indicated a positive implementation of digital solutions and a tendency from the company towards digitalisation of information exchange in the workplace. There was no correlation between the company size, work experience and the opinion of the interviewees about digitalisation. In fact, interviewees from small, medium and large companies had positive and negative opinions about digitalisation. Professionals in the construction industry described their experience with digitalisation and digitalised processes in construction projects are as follows:

Right now, everything is handled via email and AutoCAD, and plans can be reviewed digitally, but usually they are printed on the office or jobsite, engineers review it and anything that depends on architecture is sent to the sub-contractor to make the change, at the end that change only goes to that person on that email, for distributed that person has to send it to everyone. (Interviewee 05 – BIM manager)

also:

...they mostly visualise it with their smartphones, I have rarely seen them with a printed drawing. (Interviewee 07 – Project manager)

and finally:

Well the drawings are in AutoCAD. The material orders are sent via email, if we need to do a photographic report, we take the pictures and archive them, we take pictures of the tests. That is what we require the most in digital format. And the construction programs. (Interviewee 10 – Resident engineer)

These opinions indicate a positive tendency regarding the digitalization of the AEC sector. Interviewees have indicated the use of digital documents over printed ones. As interviewee 07 highlighted smartphones are being used to visualize documents and reducing the paperwork. In line with this, other interviewees noted the following:

Well in recent days, at least I see the industry moving towards using digital technologies, whether it is through the utilisation of software like Revit. In this company, we try a lot to implement digital solutions. (Interviewee 13 – Project manager)

also:

This company is on vanguard, it's true that you make drawings that you can distribute to sub-contractors, but we use Google drive and our server, with Google drive we can share it with subcontractors, and it is always updated there. There are many times that you printed for a matter of simplification for going to the job site and checking on an issue. (Interviewee 14 – Project manager)

In summary, one part of the interviewees has highlighted the transformational change towards digitalization in the construction industry. Smartphones are the only devices mentioned for visualizing

documents digitally. Sending documents digitally through email allows sharing information without printing any documents, and carrying a tablet or smartphone enables employees to visualize drawings anywhere at the job site.

- Negative perspective towards digitalization.

There is also a negative perspective regarding the digitalisation of processes in construction companies in the Dominican Republic. The main barriers perceived for the digitalisation of construction were divided into cultural issues and lack of innovation.

4.1. Cultural Issues

This barrier arises from the tradition in the Dominican Republic's construction industry of printed documentation for project approvals; this means that even if private companies are willing to submit project's documentation digitally, some of the stakeholders of the project, usually the government will require a printed copy. As noted by two of the interviewees:

...It is difficult because our culture still has established that all is submitted on paper and ultimately that becomes a necessity that we handle, with all the problems that it encompasses... (Interviewee 04 – Company director)

also:

"I think that construction has evolved in certain way, but there is still a lot of work to do, regarding getting rid of paper and ignoring the complete existence of drawings. Drawings are a vital part of a project that is needed in physical; people do not let go the habits of using paper as main resource, although little by little I have seen that we are tending to utilise digital technologies." (Interviewee 12 – Project designer)

These opinions highlight the difficulty found in the migration towards a new methodology of construction. It is a strong barrier for employees to embed technology and start doing processes differently. Nevertheless, as interviewees 12 noted, it has been noted that there is a tendency towards implementing digital solutions.

4.2. Slow Migration

The general perception of construction companies is that "there is a long road ahead" and there is still much work to be done for businesses to manage all their documentation on a digital format. Decision makers are reluctant to step forward into a full digitalisation of the industry mainly because of lack of case studies and guidelines. For instance, one of the interviewees noted that:

"There is loads, loads of paperwork, more than I thought when I came back from my builder, the directors of the company are aware of it and they are aware of where the industry is moving to. That there are few technologies applied to the industry, but many alternatives are being created. So right now, the industry is in the process of adapting to those new emerging technologies oriented to construction." (Interviewee 06 – Project manager)

also:

Exactly, but that change, that transition from paper to digital is a "bumpy ride". (Interviewee 06 – Project manager)

Despite, all the barriers, large companies in the private sector showed awareness of where the industry is moving to. To summarise the negative perspective towards digitalisation in construction, there is a lot of work to be done to eliminate the paperwork in the industry. It is important to consider the socio-economic context surrounding the companies considered in this study. Other countries might have better initiatives towards digitalisation.

4.3. Utilisation of Smart Devices in Construction Projects in the Dominican Republic

A systematic content analysis revealed distinct themes which describe the main utilisation of smart devices in the Dominican Republic construction projects. Table 4 shows the cited themes by each interviewee. The results about the utilisation of smart devices have been grouped into six categories namely: data capturing and display; data exchange; project management; contextual data request; smart metering; and material management (See Table 4). In this study, 11 out of 15 interviewees (73.0%) noted that smart devices are utilised in their organisations for data capturing and display.

- Data capturing and display

This category has the highest rank based on the number of interviewees who mentioned the implementation of smart devices for capturing, editing and storing information. Some of the interviewees stated that they use smart phones to add photos to their project reports with visual photos:

“Well we really use a lot smart phones, because we take photos for the reports and we need to have a registry of those pictures...” (Interviewee 07 – Project manager)

Table 4. Utilisations given to smart devices by content analysis

Interviewee No.	Data Capturing and Display	Data Exchange	Project Management	Contextual Data Request	Smart Metering	Material Management
1	•	•	•			
2	•					
3			•			•
4	•	•				
5	•			•		
6	•			•	•	
7	•	•		•		
8		•				
9	•	•	•			
10						
11						
12	•	•	•			
13	•	•				
14	•	•	•			
15	•	•				
Total	11	9	5	3	1	1

also:

“I use it to take pictures for my daily reports. I send them directly to my email and then download them to my computer and create daily reports...” (Interviewee 15 – Project manager)

In addition, other interviewees use smart phones to visualise drawings on the jobsite:

“...if I have a drawing and is printed and I do not want to have it on me all the time, I take a picture of the drawing, and I am with a drawing in my pocket...” (Interviewee 09 – Resident engineer)

In summary, the utilisations grouped into this category are creation, visualisation and edition of files such as drawings, punch list, calculus sheets, construction manuals, presentations, photos and reports.

- Data exchange

Smart devices are being used for exchanging of information through chats, emails, management apps, and calls. The exchanged media is photos, reports, drawings, construction manuals, calculus sheets and punch lists. Most of the interviewees noted that their organisations rely on cloud computing to store and share information in projects.

- Project management

Project management involves initiating, planning, executing, controlling and closing the work of a team to achieve specific goals and meet specific key performance indicators (Nokes & Kelly, 2007). In this context, the implementation of a smart device for project management activities considers the utilisation of such devices to support project coordination. The interviewees use smart devices for the creation of events and reminders, coordination of meetings through mobile Apps and monitoring of security cameras in real time. Smartboards are also used for information exchange among projects parties during meetings.

- Contextual data request

Contextual data gives context to a person, entity or event. A data request can be considered as contextual when the provision of information considers a context attached to the request of information to provide relevant information to the entity making the request. The interviewees stated that they use smart devices to obtain geolocation data or manuals with relevant information for the project. More specifically:

“...they use Google Earth for visualising points on the road, seeing terrain-related things, that type of things, they use the iPad for that mostly...” (Interviewee 06 – Project manager)

also:

“Yes, we use GPS ... We also used a device for marking points on a road project. You know what we use smartphones a lot for, for manuals; we have a manual for road signs. If we are on the jobsite we open it and we answer any query.” (Interviewee 07 – Project manager)

This indicates that based on the project type and project location the users will request they GPS to provide context to the smart device (in this case smartphone) and fetch relevant information. As interviewee 07 indicated, smartphones are being used for reading manuals on the job site. A more efficient approach could be achieved to provide a better user experience for the search of information in manuals. As interviewee 06 has indicated, the use of geolocation has been done on road projects. A interviewee who works in other types of projects has not indicated the need to use geo-location.

- Smart metering

A smart meter is considered as an electronic device that records consumption of electric energy in pre-defined intervals and communicates that information at least daily back to the utility for monitoring and billing (Federal Energy Regulatory Commission, 2008). In the context of this paper, smart metering encompasses the utilisation of smart devices for gathering measurements in the job site. By using smart devices to gather data, this data can then be stored, analysed and subsequently used. As stated by one of the interviewees:

“We are implementing some installations of hardware to the equipment, which connects to the Cloud and we can get information about how much terrain, a equipment moved, how much it was covered, how much it was cut. We are in the middle of a process of implementation so that information can be uploaded to a software that we have installed.” (Interviewee 06 – Project manager)

This means organisations have integrated smart devices into pre-existing equipment to track information and obtain metrics such as terrain compaction level and volume of terrain movement.

- Material management

Materials management is the function responsible for the coordination of planning, sourcing, purchasing, moving, storing and controlling materials in an optimum manner to provide a service to the customer at a minimum cost. Material management is a complex operation which can deal with campus planning and building design for the movement of materials, or with logistics that deal with the tangible components of a supply chain.

In this study, interviewees noted that they use smartphones and tablets for exchange of material-related information. They also create inventory, material requests and follow-up of material through chat.

5. CONCLUSION AND FUTURE WORK

Innovation in the Dominican Republic construction industry relies on the private sector, at the same time the private sector relies on big projects to make innovations; such projects usually come from the public sector. This interaction between sectors is how innovation is created and assimilated in the country.

The factors that affect the digitalisation of information are company size, project size and leadership. Whether a company has the will to become more digital-based, there is a big cultural barrier in the Dominican Republic society, which is the requirement from stakeholders of printed copies of the project documentation. Nevertheless, although currently, a full digitalisation is not possible, companies can improve their processes by adopting smart devices and their related technologies. Large companies have shown awareness of the direction the industry is taking towards a more digitalised work environment. The study participants expressed a positive and a negative perspective towards digitalisation of information in construction projects. On one side interviewees suggested a fluent exchange of digital documents and the implementation of smart phones to visualise drawings and

other documents. On the other hand, interviewees described strong barriers for embracing digitalised solutions in the AEC sector, such as cultural issues and slow migration of the industry.

The research reported in this paper found that, the utilisation of smart devices were grouped into six categories, namely, data capturing and display; data exchange; project management; contextual data request; smart metering and material management. Smart devices have proven their value to the construction industry by adding mobility and ubiquitous data access to construction projects. Also, smart devices could be installed to construction equipment to obtain relevant data about construction activities.

The CC plays a fundamental role as the main technology behind the ubiquity of data achievable through smart devices. Smart devices rely on CC for an effective user experience. The CC can be found behind data exchange, project management and material management utilisations. As well smart metering in some cases relies on Cloud storage to transfer data.

In the case of AR, its possible implementation within the AEC sector are focused on design and visualisation of models' data onto the jobsite. Spatial models can help the designer identify the flaws and rectify them at the design stage itself. Also, it can help create innovative designs as the architect can see the structure in real time, which can help in various advantageous changes (Agarwal, 2016). The translation of drawings into a structure is not an easy task. It involves various steps of identification of different structural elements and subsequently constructing them. Since the project is envisaged in phases, it may so happen that errors might creep in during various stages. Since AR creates a virtual image of the structure, it helps in eliminating these errors (Agarwal, 2016).

When considering BIM and smart devices there are two possible streams of information. One possibility is to stream data from smart devices to a BIM model. Whereas on the other hand a BIM model can supply data to smart devices being used on the jobsite. As one of the utilisation of smart devices in construction projects is the display and exchange of data, BIM plays a powerful role in the visualisation of useful and reliable data.

This paper shows GIS as one of the main technologies associated to Smart devices. By utilising geographic location as part of the contextual data gathered by a smart device we can embed GIS and smart devices in construction projects. Moreover, GIS and BIM have a great importance in the development of smart cities (Ma & Ren, 2017).

This study offers the utilisation of smart devices in the Dominican Republic construction industry. Consultants in the AEC sector may provide solutions to construction organisations based on the data shown in this investigation. Researchers can use this research as an insight into the implementation of smart devices in the construction industry.

Future work of this research includes analysing the drivers, barriers and critical factors for a successful implementation of smart devices and the development of guidelines for the integration of smart devices in the AEC sector.

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Manuel Silverio-Fernandez is a PhD candidate in the department of Built environment at the University of Wolverhampton. His research interests centre around the implementation of Smart devices in the construction sector and the integration of the Internet of Things and the Industry 4.0. Manuel has an MSc in Civil engineering from the University of Wolverhampton, and bachelor's in civil engineering from the Santo Domingo Institute of Technology.

Suresh Renukappa currently serves as a Senior Lecturer in the Faculty of Science and Engineering at the University of Wolverhampton. He holds a PhD in managing change and knowledge associated with sustainability initiatives for improved competitiveness. He has over 20 years of research, consultancy, project management and teaching experience in a wide range of business and management areas across industrial sectors in both developed and emerging economies. His research interests cover, but not limited to: sustainability strategies for competitive advantage; carbon reduction strategies; corporate social responsibility; leading change toward sustainability; knowledge management; public private partnerships; cloud computing; infrastructure asset management; and sustainable infrastructure investment and development. He has successfully executed more than 30 large projects and authored over 100 papers which have been published in journals, book chapters, and conference proceedings.

Subashini Suresh has over 20 years of experience in research, teaching and practice in the area of Project Management and has worked in the area of Architecture, Engineering and Construction (AEC) sector. Currently, she is a Reader of Construction Project Management at the School of Architecture and Built Environment, University of Wolverhampton. She holds a PhD in knowledge management. She received Rewarding Excellence Award for Innovation in Teaching and also for Blended Learning Tutor. She is a Fellow of the Higher Education Academy (FHEA) and Fellow of Royal Society for the encouragement of Arts, Manufactures and Commerce (FRSA). She has published over 150 academic publications, which include 32 journal papers, 96 conference papers, four articles, eight book chapters, 15 reports and three books. In the last three years, she was involved in Marie Curie Project and ERDF Project. In the EU FP7 Marie Curie IAPP (Industry and Academia Partnerships and Pathways), total cost is £850,000 (approx. €1 million), 2013 to 2017. The project was the winner of 2017 Innovation Award under the Built Environment Construction Excellence Awards in UK. Her key areas of interest are as follows: construction project management, knowledge management, building information modelling, health and safety, sustainability/ green construction, emerging technologies, quality management, leadership in change management initiatives, organisational competitiveness, business process improvement, lean construction, risk management and Six Sigma leadership.